Empirical Formula

From percentage to formula

The Empirical Formula

- The lowest whole number ratio of elements in a compound.
- The molecular formula the actual ratio of elements in a compound
- The two can be the same.
- CH_2 empirical formula
- C_2H_4 molecular formula
- C_3H_6 molecular formula
- H_2O both

Calculating Empirical

- Just find the lowest whole number ratio
- $C_6H_{12}O_6$
- CH_2O
- It is not just the ratio of atoms, it is also the ratio of moles of atoms
- In one molecule of CO_2 there is 1 atom of C and 2 atoms of O
- In 1 mole of CO_2 there is 1 mole of carbon and 2 moles of oxygen

Calculating Empirical

- Pretend that you have a 100 gram sample of the compound.
- That is, change the % to grams.
- Convert the grams to mols for each element.
- Write the number of mols as a subscript in a chemical formula.
- Divide each number by the least number.
- Multiply the result to get rid of any fractions.

Example

- Calculate the empirical formula of a compound composed of 38.67 % C, 16.22 % H, and 45.11 %N.
- Assume 100 g so
- $38.67\ g\ C \times \frac{1\ mol\ C}{12.01\ g\ C} = 3.22\ mole\ C$
- $16.22\ g\ H \times \frac{1\ mol\ H}{1.01\ g\ H} = 16.09\ mole\ H$
- $45.11\ g\ N \times \frac{1\ mol\ N}{14.01\ g\ N} = 3.22\ mole\ N$

- 3.22 mole C
- 16.09 mole H
- 3.22 mole N

•$C_{3.22}H_{16.09}N_{3.22}$

If we divide all of these by the smallest one It will give us the empirical formula

Example

- The ratio is $\frac{3.22 \text{ mol C}}{3.22 \text{ mol N}} = \frac{1 \text{ mol C}}{1 \text{ mol N}}$
- The ratio is $\frac{16.09 \text{ mol H}}{3.22 \text{ mol N}} = \frac{5 \text{ mol H}}{1 \text{ mol N}}$
- $C_1H_5N_1$ is the empirical formula

- A compound is 43.64 % P and 56.36 % O. What is the empirical formula?

$$43.6 \text{ g P} \times \frac{1 \text{mol P}}{30.97 \text{ g P}} = 1.4 \text{ mole P}$$

$$56.36 \text{ g O} \times \frac{1 \text{mol O}}{16 \text{ g O}} = 3.5 \text{ mole O}$$

$P_{1.4}O_{3.5}$

Divide both by the lowest one

$P_{1.4}O_{3.5}$

- The ratio is $\frac{3.5 \text{ mol O}}{1.4 \text{ mol P}} = \frac{2.5 \text{ mol O}}{1 \text{ mol P}}$

$P_1O_{2.5}$

- Multiply the result to get rid of any fractions.

$2 \times P_1O_{2.5} = P_2O_5$

- Caffeine is 49.48% C, 5.15% H, 28.87% N and 16.49% O. What is its empirical formula?

- 49.48g C • $\frac{1mol}{12g}$ = 4.1mol
- 5.15 g H • $\frac{1mol}{1g}$ = 5.2mol
- 28.87g N • $\frac{1mol}{14g}$ = 2.2mol
- 16.49 g O • $\frac{1mol}{16g}$ = 1.0mol

We divide by lowest (1mol O) and ratio doesn't change

Since they are close to whole numbers we will use this formula

$C_{4.1}H_{5.2}N_{2.2}O_1$

OR $C_4H_5N_2O_1$

empirical mass = 97g

Empirical to molecular

- Since the empirical formula is the lowest ratio the actual molecule would weigh more.
- By a whole number multiple.
- Divide the actual molar mass by the mass of one mole of the empirical formula.
- Caffeine has a molar mass of 194 g. what is its molecular formula?

$$x = \frac{molar\ mass}{empirical\ \ formula\ mass}$$

- Find x if

$$\frac{194\ g}{97\ g} = 2$$

2 X $C_4H_5N_2O_1$

$C_8H_{10}N_4O_2$

Example

- A compound is known to be composed of 71.65 % Cl, 24.27% C and 4.07% H. Its molar mass is known (from gas density) is known to be 98.96 g. What is its molecular formula?

Example

$71.65g\ Cl \bullet \frac{1mol}{35.5g}$ = 2.0mol

$24.27g\ C \bullet \frac{1mol}{12g}$ = 2.0mol

$4.07g\ H \bullet \frac{1mol}{1g}$ = 4.0mol

$Cl_2C_2H_4$

We divide by lowest (2mol)

$Cl_1C_1H_2$

would give an empirical wt of 48.5g/mol

Its molar mass is known (from gas density) is known to be 98.96 g. What is its molecular formula?

Its molar mass is known (from gas density) is known to be 98.96 g. What is its molecular formula?

$$x = \frac{molar\ mass}{empirical\ formula\ mass} = \frac{98.96g}{48.5g} = 2$$

2 X $Cl_1C_1H_2$ = $Cl_2C_2H_4$

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